IV CIBIO – dias 25, 26 e 27 de junho de 2019 – Curitiba, PR – Expotrade Convention Center

Bioenergy potential of the new elephant grass genotype PCEA stem grown under sustainable traits

Alessandra Camelo[1,2], Luiz Roberto Magossi[2], Sérgio Fernandes[2], Alfredo Eduardo Maiorano[2], Patricia Helena Lara dos Santos Matai[1]

[1]*Institute of Energy and Environment – IEE, University of São Paulo – USP, São Paulo, SP State, Brazil. alecameloeng@gmail.com*

[2] *Industrial Biotechnology Laboratory, Institute for Technological Research – IPT, São Paulo, SP State, Brazil.*

Abstract

Biomass has long become attractive as a renewable source for bioenergy generation in Brazil. Besides widely applied as forage for ruminants, elephant grass is also a promising raw material for several bioenergy applications, including biofuels and thermochemical conversion. The potential of this grass increases with development of new genotypes propagated by seeds, such as the *Pennisetum purpureum* x *Pennisetum purpureum* genotype called PCEA, which was developed by Embrapa Gado de Leite. The aim of this study was to characterize the new genotype "PCEA" regarding its potential for bioenergy conversion and compare with other important Brazilian feedstocks. Hence, PCEA stem samples were obtained from Embrapa Agrobiologia, processed and characterized at the Industrial Biotechnology Laboratory for structural components and by the Fuel and Lubricants Laboratory for ash and ultimate analysis at the Institute for Technological Research (São Paulo, SP State, Brazil). Results supported that PCEA stem biomass has desirable C:N ratio of 90:1, higher extractives content (19.5 wt%) which makes it desirable as fuel, and lower %S content compared with regular elephant grass of 0.17 % against 0.32 %, respectively. However, the genotype presented lower content (43.7 wt%) in comparison with RB867515 bagasse (69.3 wt%) and a regular elephant grass genotype (58.5wt%) regarding holocellulose content, fraction that includes cellulose and hemicellulose. Furthermore, the theoretical higher heating value was competitive among the perennials for direct combustion application. Overall, PCEA stem has potential to enrich, diversify and complement biomass offer, along with Brazilian sugarcane bagasse RB867515 regarding properties for bioenergy conversion.

Keywords. Renewable energy. *Pennisetum purpureum*. Perennial grass. Theoretical heating value. Holocellulose.

Introduction

Fossil fuels have powered the world to the way we currently know it, enabling industrial and technological development (LISERRE, SAUTER & HUNG, 2010). However, its exploration in ancient time brought many environmental issues, such as emissions of greenhouse gas (GHG) to the atmosphere, which are acknowledged as the main cause of climate change nowadays (ANDERSON, HAWKINS & JONES, 2016). Therefore, societies highly dependent on fossil and nuclear sources are shifting into more diverse ones regarding energy offer with major participation of renewable sources, followed by a more sustainable economic model (CLARK et al., 2006; ZOU et al., 2016). In that context, Brazil outstands worldwide with diverse energy offer as a result of commitment with the international Paris agreements for GHG mitigation, where perennial biomass plays a key role.

An outstanding feedstock known as elephant grass figured among few sources on the installed capacity of electricity generation section, with 32 MW power capacity in 2017 (EPE, 2018). The fast-growing elephant grass outstand regarding tolerance to hostile environment and diseases (JESSUP, 2013), biomass yield (MARAFON et al., 2013), quality of dry-matter (DOWLING et al., 2013), and responsiveness to Biological Nitrogen Fertilization – BNF (MORAIS et al., 2012). Besides agricultural traits with seeds instead of stalks, the use of abandoned agricultural lands to grow perennials such as PCEA contribute on preventing deforestation, along with consequent carbon stored emissions in the atmosphere (CAMPBELL et al., 2008). Moreover, C4 grasses responsive to N-fixing can be high-yielding in marginal areas, benefiting them with nutrient leaching and minimizing soil erosion occurrence (SAMSON et al., 2005). Therefore, both use of marginal lands and abandoned agricultural areas to grow PCEA minimize competition with arable lands, resulting in less food security threats. Once sustainable traits are in perspective, the bioenergy potential of a grass must be accessed and evaluated through comprehensive analysis, in order to support worthiness of large cultivation and further bioenergy conversion plant units.

According to Capareda (2014), the comprehensive analysis of vegetal biomass feedstocks includes proximate analysis (fixed carbon, ash and volatile combustible matter), ultimate analysis (C, H, N, O, and S elements), and structural analysis (ash, extractives, lignin, cellulose and hemicellulose). Such characteristics can be accessed through performance of standard laboratory protocols such as the ones developed by the National Renewable Laboratory (NREL), standard test methods elaborated by the American Society for Testing and Materials (ASTM) and the Deutsches Institut für Normung (DIN). Although standard protocols for characterization of biomass feedstocks are longstanding and time consuming, they provide comprehensive data of the raw material, including physicochemical properties and structural composition. With that, it is possible and desirable to compare the analyzed feedstock with the current local flagship in order to infer about whether it is suitable and feasible to integrate chain or substitute raw material. In that sense, this study presents structural and ultimate analyses of a new elephant grass genotype called "PCEA" in comparison with regular elephant grass and sugarcane RB867515 bagasse, providing inferences regarding bioenergy applications that may contribute to the current Brazilian energy scenario.

Material and Methods

The genuine *Pennisetum purpureum* genotype PCEA is propagated by seeds and was developed by the Breeding Group at Embrapa Gado de Leite – Centro Nacional de Pesquisa de Gado de Leite (CNPGL), and cultivated under sustainable traits at Embrapa Agrobiologia – Centro Nacional de Pesquisa de Agrobiologia (Seropédica, RJ State, Brazil). Samples of PCEA biomass were obtained at the very first harvest, 180 days after inoculation via leaf spray with *Gluconacetobacter diazotrophicus* strain LP343 aiming Biological Nitrogen Fixation – BNF (CAMELO et al., 2018). Stem samples were dried then separated, reduced to 30 mesh particulate size and stored at 8 ºC in the Industrial Biotechnology Laboratory at the Institute for Technological Research (São Paulo, SP State, Brazil).

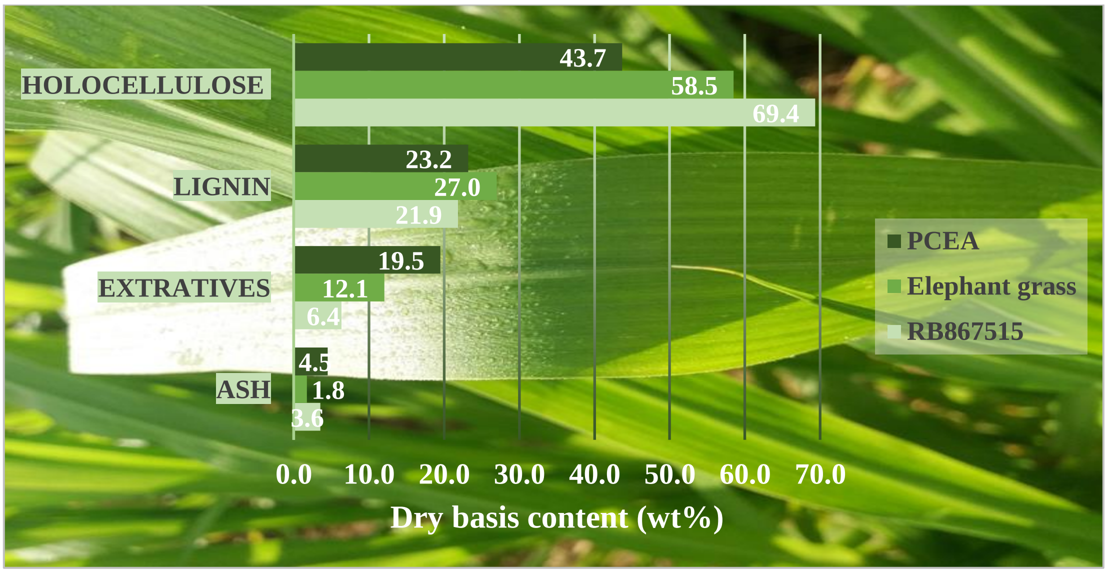
Characterization of the new elephant grass PCEA was performed at the Industrial Biotechnology Laboratory at the Institute for Technological Research – IPT (São Paulo, SP State, Brazil), following adapted standard Laboratory Analytical Procedure (LAP) protocols of the National Renewable Energy Laboratory – NREL (Golden, CO State, USA): (1) Preparation of Samples for Compositional Analysis (NREL-42620); (2) Determination of Extractives in Biomass (NREL-42619); (3) Determination of Structural Carbohydrates and Lignin in Biomass (NREL-42618); and (4) Determination of Acid Soluble Lignin Concentration Curve by UV-Vis Spectroscopy (NREL-42617). The ultimate analysis was performed by the Fuels and Lubricants Laboratory at the Institute for Technological Research – IPT (São Paulo, SP State, Brazil), following standard D3176-15 of the American Society for Testing and Materials (West Conshohocken, PA State, USA). According to Capareda (2014), the empirical correlation of biomass elemental components allows estimative of higher calorific or heating value (HHV) to be made through Boie Equation (Equation 1):

$$HHV\ (KJ.kg^{-1}): 35{,}160*C + 116{,}225*H - 11{,}090*O + 6{,}280*N + 10{,}465*S \qquad (1)$$

Results and Discussion

To the best of our knowledge, characterization of stem fraction was not performed for elephant grass grown under Brazilian edaphoclimatic conditions. With that, structural components of PCEA stems were compared with the same vegetal fraction of a genotype grown in Malaysia (MOHAMMED et al., 2015) and sugarcane bagasse RB867515 widely cultivated in Brazil (MACHADO et al., 2018), as shown in Figure 1. Overall, values reported for agricultural biomass typically range for holocellulose from 30 to 70 %, lignin from 12 to 29 %, extractives from 3 to 13 %, and ash can be found varying from 3 to 10.3 % weight content (LYND et al., 1999). PCEA steam biomass has good C:N ratio of 90:1 and the highest extractives content of 19.5 wt% among the three perennials, higher than the 13 % maximum typical range reported by Lynd et al. (1999). Higher presence of extractives generally provides higher volatile matter when combustion occurs (ZANUNCIO et al., 2014), which makes the raw material desirable as fuel (DEMIRBAS, 2007). However, the new genotype presents inferior value (43.7 wt%) when compared with the regular elephant grass (58.5 wt%) and RB867515 bagasse (69.4 wt%) regarding holocellulose, fraction that includes cellulose and hemicellulose contents. Moreover, PCEA showed higher structural content of lignin when compared with RB867515 bagasse, 23.2 wt% and 21.9 wt%, respectively. The regular elephant grass was observed with the lowest ash content of 1.8 wt%, while PCEA has 4.5 wt% and sugarcane bagasse 3.6 wt%.

Figure 1. Structural composition of PCEA in comparison with elephant grass and sugarcane (RB867515) cultivated by stalk



Source: Elephant grass from Mohammed et al. (2015); sugarcane RB867515 bagasse data retrieved from Machado et al. (2018)

The ultimate analysis (db%) and theoretical higher heating value (MJ.kg^{-1}) of the three perennials are also presented (Table 1).

Table 1. Stem characteristics of PCEA, regular elephant grass and RB867515 bagasse in dry weight basis (*db%*).

Characteristic	PCEA	Elephant grass (MOHAMMED et al., 2015)	Sugarcane (MACHADO et al., 2018)
Ultimate analysis (db%)			
Carbon (C)	45.1	48.61	43.35
Hydrogen (H)	5.49	6.01	6.25
Nitrogen (N)	0.50	0.99	0.00
Sulfur (S)	0.17	0.32	0.05
Oxygen (O)*	44.24	44.07	45.79
C:N (atomic ratio)	90:1	49:1	-
*Theoretical HHV (MJ.kg^{-1})***	17.38	19.28	17.43

*. By difference; **. Boie Equation

Differences regarding C content are observed to infer on calorific power, where the higher 48.61 %C content corroborated higher 19.28 MJ.kg^{-1} HHV observed for the regular elephant grass. The PCEA stem HHV of 17.38 MJ.kg^{-1} stands within range value for agricultural feedstocks from 10 to 18 MJ.kg^{-1} dry basis (CAPAREDA, 2014). With that, PCEA stem supply is also competitive with the other perennials for direct combustion applications, including pellets and briquettes. The low %S content in PCEA compared with regular elephant grass outstands, once it is desirable for renewable sources and indicates that SOx emissions during combustion are not of concern for this bioenergy source.

Conclusions

Overall, PCEA stem has potential to enrich, diversify and complement biomass supply offer in Brazil regarding its competitive properties for bioenergy conversion. Furthermore, ease and sustainable agricultural traits enhanced through seed propagation and responsiveness to Biological Nitrogen Fixation (BNF), which reduce CO_2 emissions to the atmosphere, are some attractive features of this new genotype. Finally, Brazilian stakeholders of the energy sector are invited to invest on development of dedicated energy crops for Brazilian edaphoclimatic conditions, such as PCEA, that also avoid competition with food supplies and arable lands providing good quality feedstock for bioenergy generation.

Acknowledgments

The authors are thankful to Dr. Francisco Ledo (CNPGL), Dr. José Ivo Baldani and Dr. Marcia Soares Vidal (CNPAB) for providing PCEA stem samples, and gratefully acknowledge the financial support of the Fundação de Apoio ao Instituto de Pesquisas Tecnológicas (FIPT) - New Talents Program of the Institute for Technological Research (NT-IPT). Alessandra Camelo was sponsored by the Coordination for the Improvement of Higher Education Personnel (CAPES) - Social Demand/Program of Support to Graduate Activities at the Institute of Energy and Environment, University of São Paulo (IEE-USP).

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